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FACTORS AFFECTING THE SIZE OF FERRUGINOUS HAWK HOME RANGES

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ABSTRACT.—We used radio-telemetry to track movements of seven adult male Ferruginous Hawks (*Buteo regalis*) in southcentral Washington. Home range size was estimated for each male using minimum convex polygon, harmonic mean, adaptive kernel, and fixed kernel-based methods. Minimum convex polygon and harmonic mean home ranges were significantly larger than those previously reported for Ferruginous Hawks. Home ranges varied substantially among males (mean = 90.3 km^2, range = 17.7–136.4 km^2). There was no relationship between home range size and brood size; however, there was a significant relationship ($r^2 = 0.964$, $P = 0.018$) between home range size and the distance from the nest site to the nearest irrigated agricultural field where some males hunted. Kernel-based estimates showed two distinct core areas for most males, one around the nest and a second in the agricultural fields where they hunted. *Received 25 Aug. 1997, accepted 29 Oct. 1997.*

The Ferruginous Hawk (*Buteo regalis*) is a large grassland raptor that breeds in the shrub-steppe and semi-arid regions of western North America (Olendorff 1993). The species is thought to be sensitive to human-caused disturbance in its nesting areas (Lokemoen and Duebbert 1976, Bechard et al. 1990). Habitat degradation caused by agriculture and overgrazing have been reported as a threat to the species' survival in North America (Howard 1975, Thurow et al. 1980, Cottrell 1981, Gilmer and Stewart 1983). In Oregon and Washington, the species is on the periphery of its range and is currently listed as Threatened in Washington which has an estimated population of 50 to 60 breeding pairs (Wash. Dept. Fish Wildl. 1996). This study was undertaken to provide information about the spatial use patterns of the Ferruginous Hawk in southcentral Washington for use by the state Department of Fish and Wildlife in their recovery plan for the species.

Herein, we report home range estimates for adult male Ferruginous Hawks in southcentral Washington and compare them with results previously reported in the literature. We estimate home range size using four different techniques: the minimum convex polygon (MCP; Mohr 1947), harmonic mean (Dixon and Chapman 1980), fixed kernel, and adaptive kernel-based (Worton 1989, Kenward 1990) methods. Lastly, we relate variability in individual home ranges to factors such as brood size and habitat type around the nest site, and examine possible effects of habitat on home range size.

STUDY AREA AND METHODS

We conducted the study on and adjacent to the 1482 km^2 U.S. Department of Energy's (DOE) Hanford Site (site) located in Benton and Franklin counties, Washington. The Columbia River borders the site to the north and east and the Yakima River borders the site to the south. Rattlesnake Mountain, at 1100 m above mean sea level on the western boundary, is the main topographic feature in the region. With the exception of Rattlesnake Mountain and the Horse Heaven Hills south of the site, topography is relatively flat.

The study area is in the sagebrush (*Artemesia tridentata*)/bluebunch wheatgrass (*Agropyron spicatum*) vegetation zone described by Daubenmire (1970). Climate is hot and dry during summer and moderately cold and wet during winter. Annual precipitation averages 16.5 cm, but ranges from 7 to 30 cm.

There has been no grazing or agricultural production on the Hanford Site for the past 50 years. However, the site is dominated by a recovering sagebrush/cheatgrass (*Bromus tectorum*) vegetation type characteristic of areas that have recently burned. Areas surrounding the Hanford Site in Benton and Franklin counties are intensively managed for agriculture. South and west of the site, dryland farming (e.g., dryland wheat production) is the primary land use. East of the site and along the Yakima River to the south, the land is used to

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produce crops that require irrigation (e.g., alfalfa and potatoes).

We searched for occupied nests during nest building and incubation periods (March through early May) of 1994 and 1995. Surveys were conducted by scanning from a vehicle or on foot using 10× binoculars and a 60× spotting scope. Initial surveys targeted historical nest locations and were conducted from a distance of more than 100 m to minimize the risk of researcher-caused abandonment. Surveys were also conducted in other areas of suitable habitat (Bechard and Schmutz 1995) to locate new territories. Once located, occupied nests were monitored at least three times each week from a distance more than 100 m for the remainder of the incubation period to determine approximate hatching dates.

We trapped adult Ferruginous Hawks during the early brood rearing portion of the nestling season (when young were about 10 days old), which occurred between 17 May and 3 June 1994 and between 16 May and 10 June 1995. We used a dho-gaza net placed near the nest with a live Great Horned Owl (*Bubo virginianus*) for a lure (Bloom 1987). Six adult males were captured in 1994 and three in 1995. Each male was fitted with a 15-g Advanced Telemetry Systems (Isanti, MN) radio-transmitter, which was tied and glued to the two newest looking retrices, and a U.S. National Biological Service aluminum leg band was attached to the right leg. We measured the toe pad length, mass, and wing chord of each individual captured to verify sex (Gossett 1993).

Tracking began the day after capture and continued until the male could no longer be located in his home range (approximately mid-July). All locations were based on visual observations of perched or flying hawks and locations were obtained during all daylight hours. During the course of the breeding season, we attempted to locate each male at least five times during each of nine different two-hour periods [e.g., 04:00–05:59, 06:00–07:59, etc. (PST)], in order to include observations during all possible activity periods. We attempted to locate each male at least one time every other day. Once located, the male was observed for as long as possible. However, because of large home ranges that often crossed the Columbia River, extended observations were often not possible.

When we began a second study of dietary habits (Leary 1996), one male was tracked continuously for 4–5 h each day. However, a minimum of a 1-h interval was maintained between successive recorded locations to avoid auto-correlation (Andersen and Rongstad 1989). Although probably not statistically independent (Swihart and Slade 1985), we considered locations taken at 1-h intervals to be biologically independent (Lair 1987, Ganey and Balda 1989). In support of this assumption, we observed that a male could easily travel over its entire home range within 1 h. All locations were recorded where the hawk was observed with a Magellan Geographical Positioning System (GPS) using Universal Transverse Mercator (UTM) coordinates. Locations taken with this GPS unit are accurate to ± 100 m, so we consider home range estimates to be accurate to 0.1 km^2. While tracking males and doing nest observations for our study of dietary habits; the time, location, habitat, and outcome of all foraging strikes observed were recorded.

Home range size was estimated for each male based on the 95% MCP (Mohr 1947), kernel (Worton 1989), and harmonic mean (Dixon and Chapman 1980) methods. All estimates were calculated using Ranges V software (version 5.1; Kenward 1990) on an IBM-compatible computer. We estimated home ranges using the 95% MCP method because it is the one most commonly reported in the literature. Because of small sample sizes and unequal variances among results from this and previous studies, we used a nonparametric Mann-Whitney test (Zar 1984, SAS Institute 1990) to compare our results with those reported previously for Ferruginous Hawks.

We used the 95% MCP method to calculate area observation curves for each male and to determine whether sample sizes were large enough to give accurate estimates of home range size (Odum and Kuenzler 1955). To test this, we randomly selected five locations for each individual and estimated the 95% MCP home range. The process was repeated, randomly adding five more locations and estimating home range size until all locations had been included. At the point where each additional location produced less than a 1% increase in the home range size, sampling was deemed adequate.

Linear regression (Zar 1984) was used to determine if home range size was related to brood size or if home range size was related to the distance from nest to the nearest irrigated agricultural fields. For all statistical tests, probability values of ≤ 0.05 were considered significant.

Using the harmonic mean and kernel-based methods, we estimated home range size using nine contour levels to determine which one most accurately described the area used by each male. With the adaptive kernel method, we also estimated home ranges for each male using eight smoothing factors (Worton 1989, Kenward 1990).

RESULTS

We estimated home range size for seven of nine males that were radio-tracked during 1994 and 1995 (Table 1). One male removed its transmitter less than one week after attachment so home range data were not available for that individual. Another male (Webber Canyon) was excluded from the analysis because he did not breed (he was a floater). The Route 2 male was captured and tracked both in 1994 and 1995 when it used the same nest. For analysis purposes, we considered data collected on this male during the two years as separate and independent estimates.

An average of 60 locations (range 16–110)

TABLE 1. Minimum convex polygon home range estimates for seven adult male Ferruginous Hawks in southcentral Washington during 1994 and 1995. Sample size is number of locations taken.

Bird	95% MCP home range[a]	Sample size	Days tracked
Beck Road (1994)	122.7	52	39
Chandler Butte (1994)	75.0	60	54
FFTF #1 (1994)[b]	8.9	40	32
Rt. 2 (1994)	100.5	88	61
Rt. 2 (1995)	89.3	51	42
WPPSS #1 (1995)	136.4	110	58
FFTF #4 (1995)	17.7	16	9[c]
Mean	78.6	60	42

[a] Home ranges in km^2.
[b] Not included in any analysis.
[c] Transmitter failed after 9 days.

were obtained for each male (Table 1). Based on area observation curves (Odum and Kuenzler 1955), adequate sampling was achieved for all but one male (FFTF #1). Therefore, data from this male were not included in the analysis.

With the exception of FFTF #1, all males spent much of their time long distances from their nests. Three males were located more than 10 km from their nest 27% of the time (Fig. 1). As a result, home ranges covered extensive areas. Mean home range size calculated using the 95% MCP method was 90.3 km^2 (SD = 41.9, range = 17.7–136.4 km^2, $n = 6$; Table 1). We compared these results with those reported by Platt (1984), McAnnis (1990), and Harmata (1991) using a Mann-Whitney test; home ranges from our study (Fig. 2) were significantly larger ($P = 0.001$). Results from Smith and Murphy (1973), Wakeley (1978), and Janes (1985) were excluded from statistical comparisons because they did not use radio-telemetry to determine home range size. Mean home range size from our study was approximately 17 times that predicted for a raptor on the basis of body mass (Newton 1979).

Variability in home range size among males was not related to brood size ($r^2 = 0.238$, $P > 0.05$). In fact, the WPPSS #1 male fledged one young and had a home range of 136.4 km^2, while the FFTF #4, Chandler Butte, and Beck Road males fledged three young each and had home ranges of only 17.7, 75.0, and 122.7 km^2, respectively.

Home range size was significantly related to distance from the nest to the nearest irri-

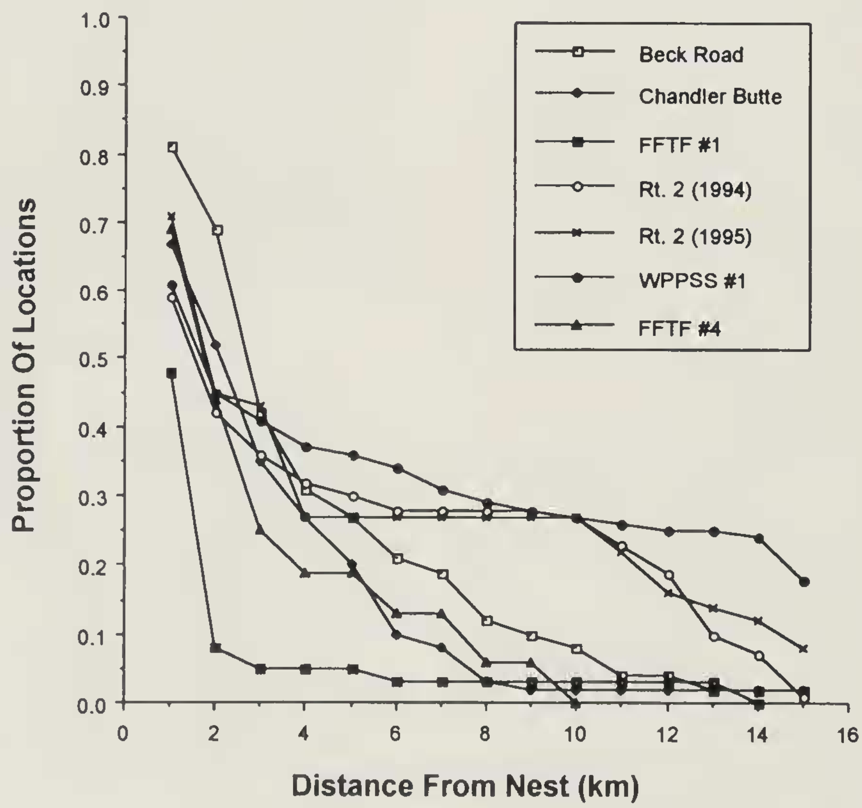

FIG. 1. Distance from the nest site for telemetry locations of seven adult male Ferruginous Hawks in southcentral Washington during 1994 and 1995. Symbols represent the proportion of locations that were greater than that distance from the nest site.

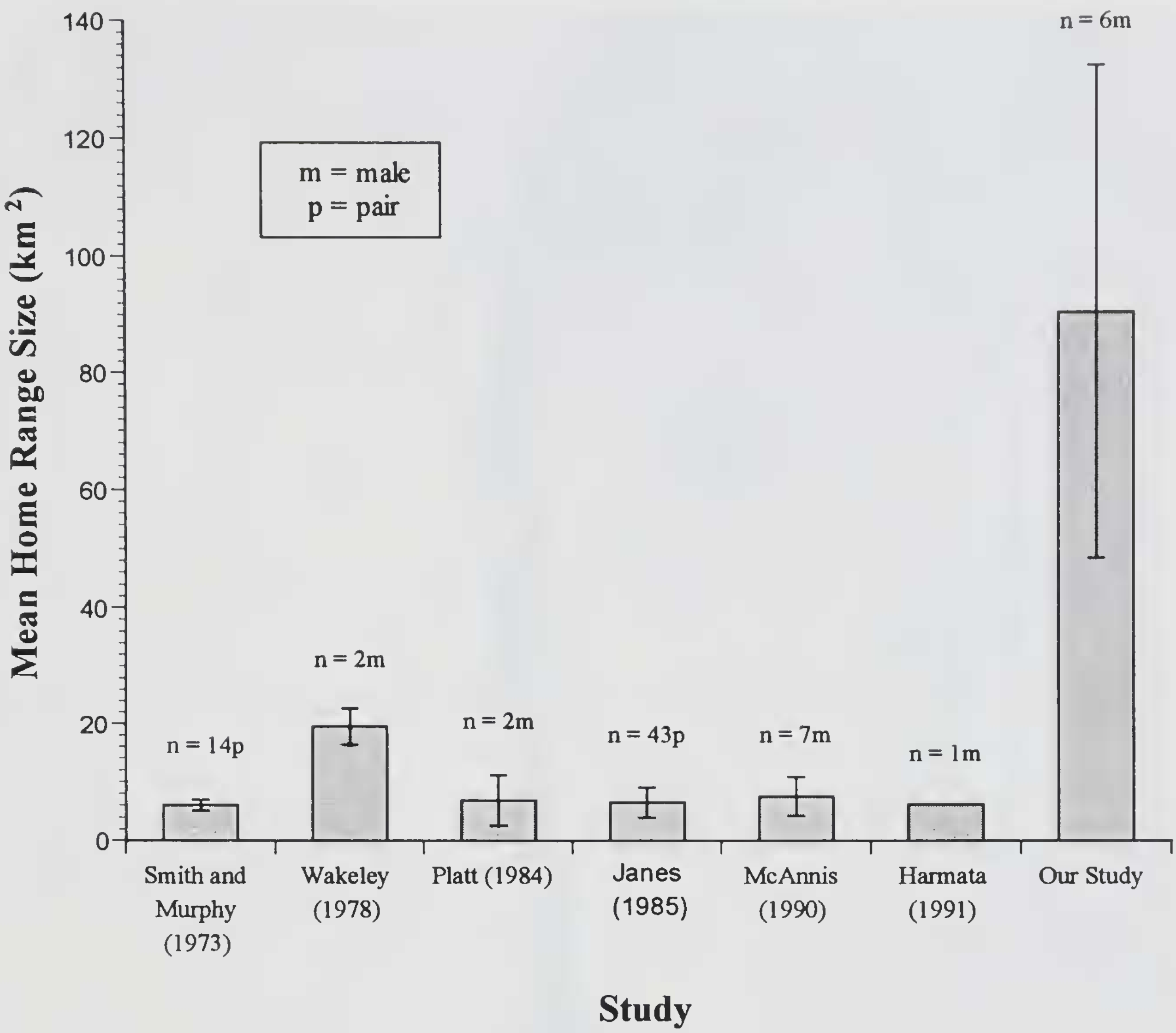

FIG. 2. Comparison of 95% minimum convex polygon mean home range estimates from this study with those previously reported in the literature for Ferruginous Hawks.

gated agricultural field, for the four males that foraged extensively in those fields ($r^2 = 0.964$, $P = 0.018$). FFTF #4 nested closest to the surrounding agricultural fields (1100 m) and had the smallest home range (17.7 km^2), while WPPSS #1 nested the farthest from agriculture (7000 m), and had the largest home range (136.4 km^2).

Despite being successful on 21% of the foraging strikes that occurred in shrubsteppe habitats compared to only 14% of strikes in agricultural fields, all but one male (FFTF #1) hunted extensively in agricultural fields. Of the 49 foraging strikes observed, 71% occurred in agricultural fields. This result may underestimate the importance of agricultural fields because of difficulty in following individuals and observing strikes in fields more than 10 km from the nest. In comparison, strikes that occurred in shrubsteppe habitats were usually within 400–500 m of the nest site and therefore were easily observed. Adults were occasionally observed hopping on the ground late in the evening near their nests, apparently eating insects. However, because we were not certain that they were foraging, these observations were not counted as foraging strikes.

Four males that nested on the site hunted primarily in distant agricultural fields, producing two activity centers or core areas within their home ranges (Fig. 3). One core area was centered in the shrubsteppe habitat around the nest and the second was far removed in the agricultural fields where the individual was hunting. Portions of the ranges between these two core areas were used only as travel corridors. There was a wide variation in core area estimates using different methods, different contours, and different smoothing parameters

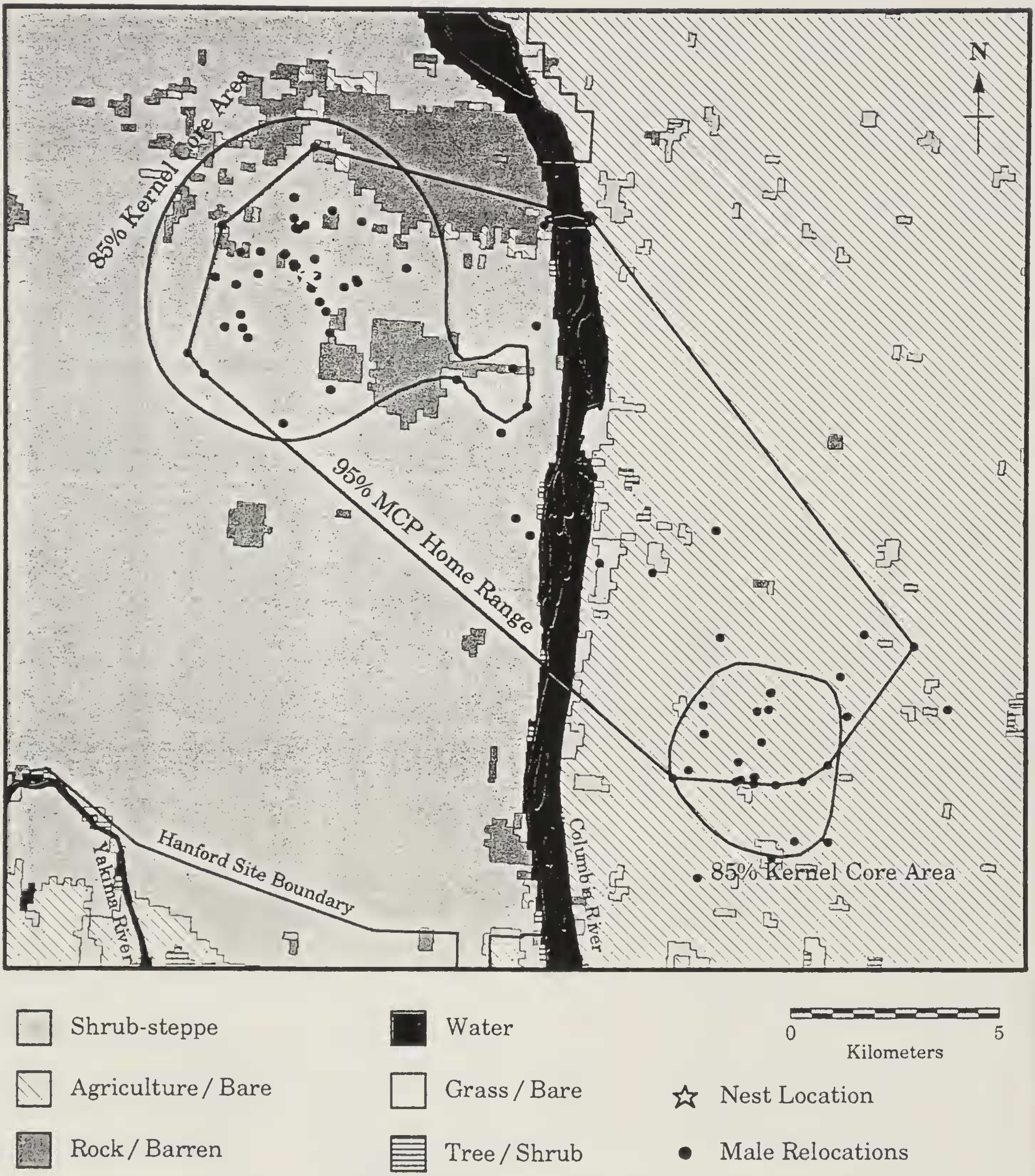

FIG. 3. Locations and home range estimates (95% MCP and 85% adaptive kernel with 0.7 smoothing parameter) for the WPPSS #1 male. This home range, with its two core areas, is representative of the home ranges of all males who nested on the Hanford Site and hunted in the agricultural fields that surround the site.

(Table 2). Based on the clustering of fixes, we suggest that the 85% adaptive kernel method with a smoothing parameter of 0.7 best represented the area actually used by each male (Fig. 3). Using this method, mean core area size was 35.0 km^2 (SD = 18.3, range = 7.7–60.3, n = 6). No previous reports of Ferruginous Hawk home ranges have used this method for estimating core areas. However, McAnnis (1990) used the 50% harmonic mean method to estimate core areas for Ferruginous Hawks in southern Idaho and obtained a mean core area of 2.2 km^2. Using the 50% harmonic mean method, mean core area

TABLE 2. Comparison of core area estimates for seven adult male Ferruginous Hawks using three different non-parametric estimation techniques (all estimates in km^2). Also shown are estimates from the adaptive kernel-based method using two different smoothing parameters (1.0 and 0.7).

Bird	85% Harmonic mean	85% Fixed kernel	85% Adaptive kernel (1.0)	85% Adaptive kernel (0.7)
Beck Road	73.4	80.3	64.1	45.1
Chandler Butte	73.2	63.5	35.7	22.1
FFTF #1	9.7	7.7	6.8	5.7
Rt. 2 (1994)	71.0	66.5	61.4	38.7
Rt. 2 (1995)	94.3	104.9	49.2	35.8
WPPSS #1	89.8	88.5	75.1	60.3
FFTF #4	17.2	35.0	11.3	7.7
Mean	61.2	63.8	43.4	30.8

from our study was 8.7 km^2, which is significantly larger than the core areas reported by McAnnis (1990; $P = 0.005$).

DISCUSSION

Using the MCP method, home ranges from our study were significantly larger than those reported in previous studies on Ferruginous Hawks (Smith and Murphy 1973, Wakeley 1978, Platt 1984, Janes 1985, McAnnis 1990, Harmata 1991). Differences in home range estimates among studies may reflect differences in habitat quality or prey densities. Newton (1979) demonstrated a relationship between home range size and habitat quality, which translates to prey density and prey vulnerability, for the European Sparrowhawk (*Accipiter nisus*). A similar relationship may also exist for Ferruginous Hawks.

Habitat quality or prey availability at our site may have been poorer than at other studied sites. For example, McAnnis (1990) reported the majority of foraging attempts in her study area occurred within 1 km of the nest site. In our study area, males consistently traveled distances greater than 10 km from the nest site to forage in irrigated agricultural fields. Kernel analysis revealed two distinct core use areas where the male either roosted or hunted. The distance between these core areas was closely related to the distance from the nest to irrigated agricultural fields. This suggests that prey may have been less available in habitats around nest sites and more available in the irrigated agricultural fields.

Wakeley (1978) did not report estimates of core areas, but he did indicate that a high proportion of locations were in a small portion of the home range and that both males in his study used one block of their range for the majority of their foraging activities. His home range diagrams include large areas that were never used by the hawks. McAnnis (1990) reported core areas using the 50% harmonic mean method. Core areas in her study were concentrated around the nest site, indicating that males were foraging and resting in the same areas. Because of the way in which locations were distributed in our study, the harmonic mean method also included large areas that were never used by the male.

The home ranges of the hawks we observed were large and often crossed rivers and other geographical features; therefore, visual observations would not have been possible without the use of radio-telemetry. We rarely observed males foraging within sight of their nests. In fact, three of the males were observed foraging more than 15 km from their nest. In contrast, Smith and Murphy (1973), Wakeley (1978), and Janes (1985) observed birds and estimated home ranges without the use of telemetry, indicating that males in their studies did not travel far from the nest site during any of their daily activities.

Wakeley (1978) indicated that males do all of the hunting for the family during incubation and most of the brood-rearing season. He did not observe females hunting until young were almost one week from fledging. Although we did not use radio-telemetry to track females, on several occasions while tracking males and conducting nest observations (Leary 1996), we observed females out hunting when their young were only two weeks old. This behavior may be another indication that food was less available. Males may have been unable to provide for the entire family because of the long distances they had to travel to find prey.

Wakeley (1978) reported that alfalfa fields were the only places where he found appreciable numbers of northern pocket gophers (*Thomomys talpoides*), the primary prey species of Ferruginous Hawks in his study area. Schmutz (1987) determined that ground squirrels (*Spermophilus* spp.), another favorite prey species of the Ferruginous Hawk, also occurred in high numbers in agricultural fields.

Bechard (1982) found that prey was most abundant in cultivated fields, but that Swainson's Hawks (*Buteo swainsoni*) did not hunt in these fields until crop harvest reduced the density of the plant canopy. We observed male Ferruginous Hawks hunting in alfalfa fields throughout the breeding season. This may have been possible because alfalfa fields are typically harvested several times a year enabling hawks to consistently find fields with low canopy cover.

All nests on the Hanford Site were located in a recovering (recently burned) sagebrush/cheatgrass habitat. Nests off the site were surrounded by dryland agriculture (primarily wheat fields), but off-site males also had large home ranges. This may have been related to the fact that wheat fields are only harvested once a year near the end of summer and thus have high canopy cover throughout most of the breeding season. This probably limited prey availability, forcing males nesting and foraging in dryland agricultural areas to travel long distances to locate prey. Wakeley (1978) determined that canopy cover was the most important factor influencing choice of foraging habitats for Ferruginous Hawks, and these hawks used dense cover habitats such as grass, rush grass (primarily *Juncus* spp.), and grain fields significantly less than expected based on availability. Bechard (1982) also found canopy cover to be an important factor in the choice of foraging areas for Swainson's Hawks.

Several authors have reported that the conversion of native habitats to agriculture and other uses may threaten the Ferruginous Hawk (Howard 1975, Thurow et al. 1980, Cottrell 1981, Gilmer and Stewart 1983, Schmutz 1984). Others have reported negative impacts of agriculture on breeding densities and productivity of the species (Schmutz 1989, Olendorff 1993). Howard and Wolfe (1976) predicted that the conversion of native vegetation to monotypic stands of agricultural crops might reduce breeding densities and reproductive success because of increased disturbance, loss of nest sites, and the reduction of prey populations. To the contrary, our data indicate that in areas where prey densities are low, Ferruginous Hawks rely on agricultural fields for foraging. Our findings that Ferruginous Hawks traveled out of shrub-grassland habitats and into agricultural areas suggest that some types of agriculture, such as alfalfa fields, can be beneficial to these hawks.

Ferruginous Hawks in our study area may nest on the Hanford Site and forage in distant agricultural fields because of a lack of suitable nest sites in the agricultural areas or because there is too much disturbance in those areas. To further our understanding of this species' ecology, future research should examine prey densities in the various habitats and assess female activity budgets. Olendorff (1993) suggests constructing artificial nest platforms for Ferruginous Hawks in areas of suitable habitat. This should be considered as a management strategy in our study area.

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